VALIDATION AND CALIBRATION OF J-ERS-1 SAR IMAGERY

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Introduction

A joint calibration experiment between the synthetic aperture radars (SAR) onboard NASA/JPL's AIRSAR and Japan's NASDA J-ERS-1 satellite was performed by co-temporally imaging Manu National Park in Peru on June 7, 1993. (Manu National Park is the largest tropical rain forest biosphere reserve on Earth.) The data from both instruments were subsequently processed and calibrated at their respective institutions. *In situ* data at the site in Peru consisting of ground and aerial photographs, GPS coordinates, dielectric measurements, ecological characterization, rain forest structural parameters, and vegetation species identification were collected in early September 1993.

Some of the objectives of this experiment were to quantify the relative calibration of AIRSAR and J-ERS-1 data, identify ecological habitats from radar backscatter, and to classify backscatter response due to structural characteristics of the rain forest. Since temporal, global coverage of the J-ERS-1 L-band HH polarization SAR exists, data from this instrument may provide a means for both remote ecological habitat identification and the ability to monitor the extent and conversion of rain forests as man encroaches on ever more remote regions of the world.

people

This paper will include a discussion of the calibration of the SAR instruments. For a description of the structural characteristics of the rain forest in the region that was imaged, and the ability of the L-band HH channel to discriminate different forest structural types, refer to [4].

The Joint AIRSAR/J-ERS-1 Calibration Experiment

The primary objective of this experiment was to examine the relative calibration of the J-ERS-1 and AIRSAR data, acquired at the same track angle on the same day. This is possible because the tropical rain forest in this area is homogeneous and of wide extent.

Manu National Park is a relatively pristine tropical rain forest biosphere reserve located around the Rio Manu, a tributary of the Amazon River. A biological research station at Cocha Cashu has been used for many years as a base from which to study the wildlife and forests of the park. Many endangered species such as the Giant River Otter and the Jaguar are protected and studied by scientists interested in the preservation of these species and their habitats. Identification of their habitats is of crucial importance. One additional objective of this experiment, therefore, was to determine the capability of identifying different ecological habitats with J-ERS-1 data. A small team was sent to Manu National Park for ground classification of forest species identification and forest structural characteristics, and identification of distinct signatures in the SAR data.

The incidence angle of the J-ERS-1 data is approximately 35 degrees, while the incidence angle of the AIRSAR data varies between 15 degrees and 65 degrees. The scattering behavior changes with incidence angle, so the comparison between AIRSAR and J-ERS-1 data will be restricted to those portions of the AIRSAR scene that occur at the incidence angle of J-ERS-1. See table 1 for a comparison of the AIRSAR and J-ERS-1 instruments.

	AIRSAR	J-ERS-1
Frequency band	PLC	L
Projection	slant	ground
Polarization	quad-pol	HH
Swath (az x range)	12x7Km	60x60Km
Resolution (az x range)	18 x 7 m	25 x 25 m
Pixel size (az x range)	12 x 7 m	12.5x 12.5 m
Noise-equivalent σ^0 (dB)	P:-40dB L:-40dB C:-30dB	-18dB
Number of looks	16	4
Incidence angle	O-65 degrees	35 degrees

Table 1. AIRSAR - J-ERS- 1 comparison

The data collected at this site include a high resolution J-ERS-1 SAR image proccsscd by NASDA; 16 AIRSAR "compressed Stokes Matrix" sccncs; 8 "synoptic single channel " scenes; ground and aerial photographs; GPS coordinates of distinctive features such as river bends, unusual radar signatures, and human habitats; dielectric measurements of trees; ecological characterization of regions with distinct radar signatures; rain forest structural parameters; and vegetation species identification along the Rio Manu.

Calibration of J-ERS-1 Data - Rain Forest Analysis

The J-ERS- 1 data was proccsscd and calibrated by the NASDA processing facility. The data has been resampled to the ground range projection, and has had a radiomctric correction applied, consisting of the effect of the antenna pattern, the effect of changing surface area with changing incidcncc angle, the gains of the system, and the calibration from RCS (radar cross section) to normalized RCS (σ^0). The data was calibrated in an absolute sense by the NASDA processing facility (a calibration constant is supplied). The antenna pattern correction was verified by analysis of tropical rain forest data. [1]

Analysis of the J-ERS-1 and AIRSAR rain forest data revealed the following calibration results:

Noise level estimates for NASDA products were calculated as a function of slant range by selecting the darkest regions (rivers, lakes) present in two full resolution images of the Manaus region obtained in July and October of 1993 (image ID cO171 a14 and c0230b1 9). Figure 1 shows the noise following a parabolic pattern which is expected due to radiometric correction. The noise level at its lowest peak is not far from the nominal -20.5 dBm^2, and averages over the entire range at roughly -17.5 dBm^2.

Noise Estimatc Graph

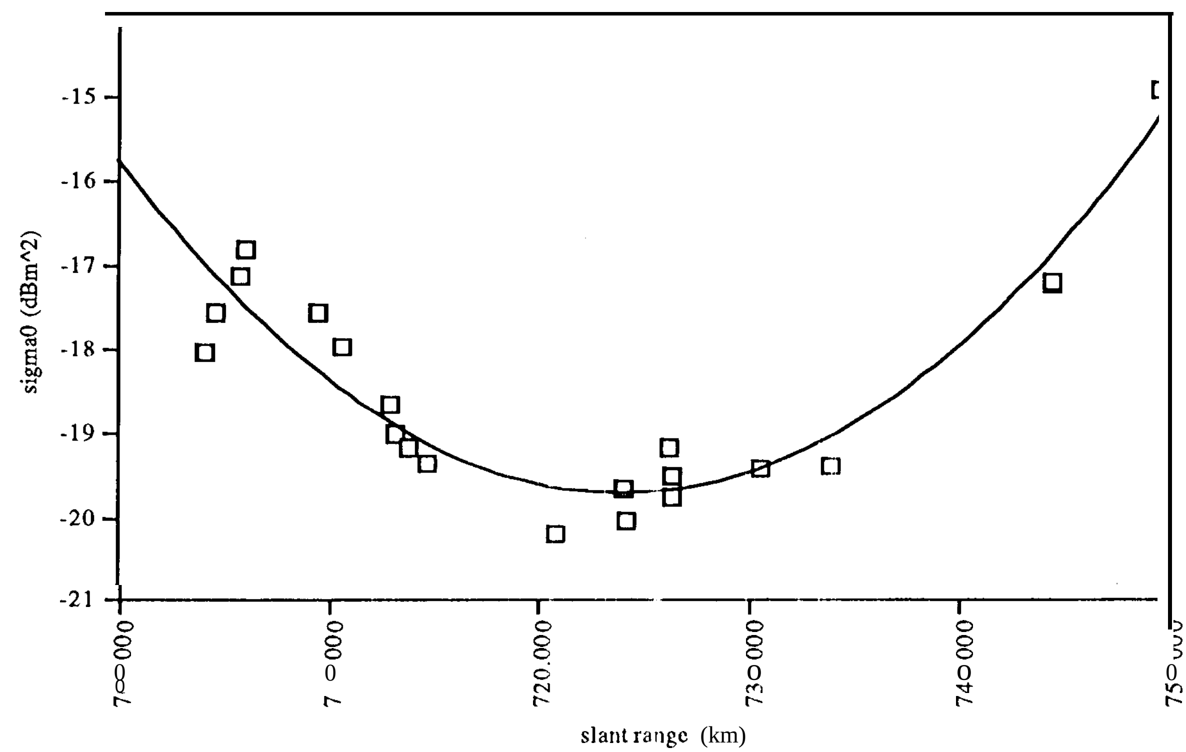

Figure 1. Noise Estimatc

As a function of range, the Sensitivity Time Control (STC) function sometimes results in calibration errors with an order of magnitude of 0.3 dB [2]. The STC is used to increase the dynamic range of the received signal before it is quantized by the SAR's 3-bit ADC. A quick examination of J-ERS- 1 images of Delta Junction, Alaska processed and calibrated at the Alaska SAR Facility (ASF) did not show any sign of this error. This error may therefore be correctable during processing. This error manifests itself as slight light and dark bands in the range direction. The locations of these bands are somewhat predictable, and in some cases an empirical approximate correction may reduce the magnitude of the error.

If wc average several columns of data (corresponding to the range direction) for all azimuth samples for an entire image, and then plot the result, wc observe, in addition to the above mentioned STC errors, random slopes to the data. This is probably due to inaccurate knowledge of the roll angle of the SAR sensor, resulting in a slightly shifted in range antenna pattern correction. For example, figure 2 is a plot of the average backscatter as a function of range for three scenes acquired of Manu National Park. For the datatake from June 1993, the plot is fairly flat, but for the two scenes from August of 1992, wc scc a gradual decrease in backscatter with range. In addition, wc scc that there is an offset of at least 1 db between the two dates, which could be either seasonal change in the backscatter, or a calibration offset. We caution that the three scenes are not of the same area, and so limited conclusions about this offset can be made. However, the change in slope is probably duc to a different amount of error in the roll angle estimate for the two dates. Other rain forest data sets that wc have examined have shown the backscatter slope with range varying between positive and negative values, corroborating this conclusion. We observe no trend in the along track (azimuth) direction.

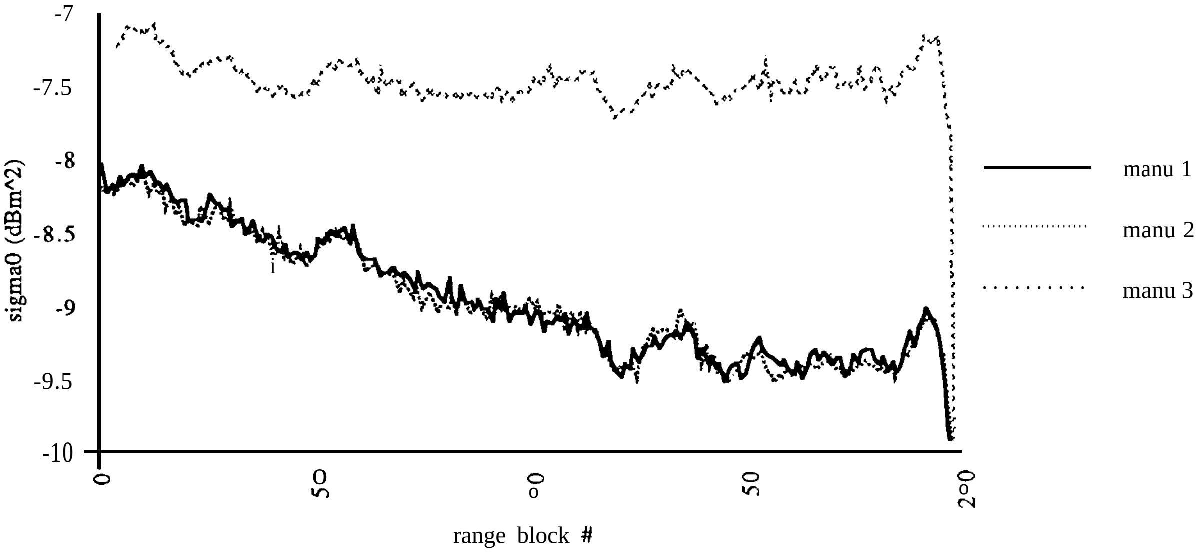

Figure 2. Range calibration analysis

The table below indicates the scene from which the above curves were obtained.

Reference Name	Image ID	ath-row	Overflight Date
manu1	c0068a18	430-321	92 August
manu2	c0064b27	431-320	92 August
manu3	cO064b26	430-321	93 June

Table 2.

The short term stability of the instrument was examined by comparing rain forest measurements made within seconds of each other, and several months apart. Adjacent images along the same track, and from parallel nearby tracks were characterized by the average over the whole image and compared. Since these scenes arc not identical to each other, this analysis is not definitive; there may bc features in the image which result in some inherent difference between the scenes. However, the scenes were chosen to be dominated by rain forest, with a minimum of river, urban, and mountainous areas. The result is shown in figure 3. This plot shows that within a given short interval of time, the different scenes arc very consistent with each other, and could bc due solely to variations in the actual backscatter for each scene. However, over many months, there can be significant differences which may be due to time dependent calibration offsets which have not been accounted for during processing.

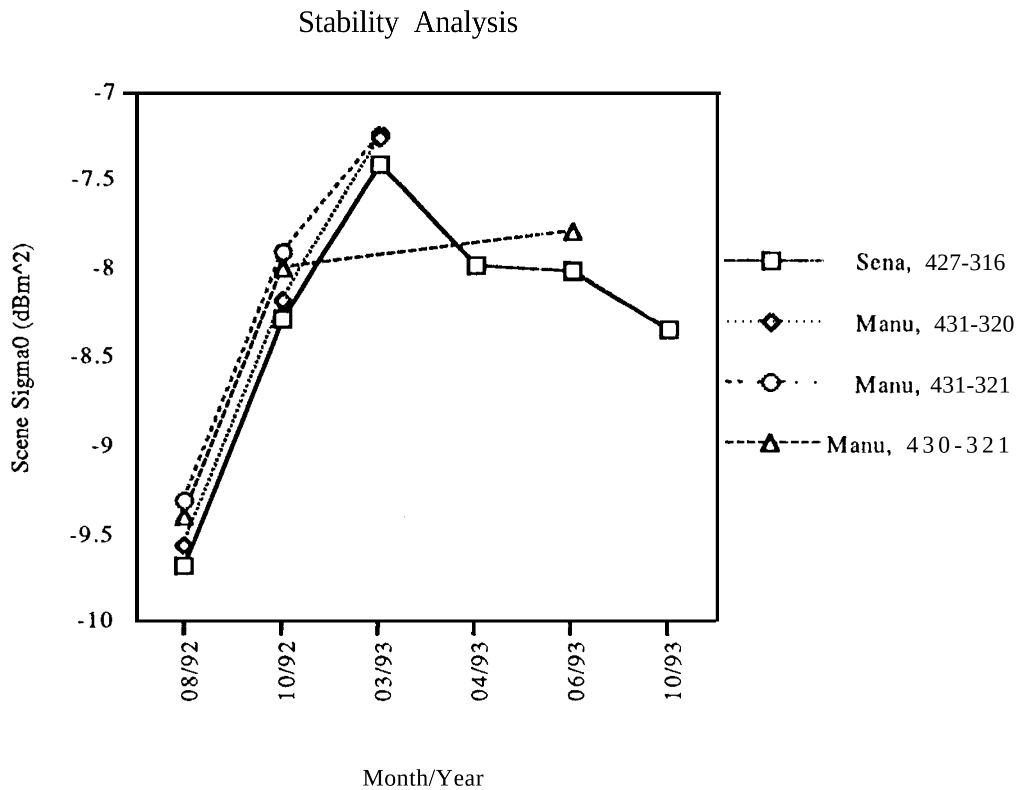

Figure 3. Stability analysis.

Finally, a comparison was made between AIRSAR L-band HH and J-ERS- 1 rain forest images obtained over Manu National Park, Peru (both obtained on June 7, 1993). AIRSAR measurements of the backscatter were made at an incidence angle of 35 degrees, to agree with the incidence angle of J-ERS- 1. Then, the same area was measured in the J-ERS- 1 image. Several hundred backscatter measurements from each instrument were averaged for each of three forest types. The results arc shown in table 3. This table shows that for the time of the June 7, 1993 data takes, the AIRSAR and J-ERS- 1 instruments were about 1 db different in terms of calibration.

	AIRSAR	JERS-1
Hill Forests	**-6.5 ± 0.1**	**-8.0 ± 0.1**
Upland Forests	**-6.0 ± 0.2**	-7.4 ± **0.3**
Floodplain Forests	**-6.8 ± 0.2**	**-7.8 ± 0.2**

TaMe 3. **Rain forest measurements**

Calibration of J-ERS-1 data - Corner Reflector Measurements.

The AIRSAR compressed Stokes matrix data was calibrated by the AIRSAR processor as described in [3]. Prior to and immediately after the deployment to South America, AIRSAR several times imaged the Rosamond Dry Lake calibration array. This calibration array consists of trihedral comer reflectors oriented towards the airborne radar. In September 1993, AIRSAR imaged an array of corner reflectors at Kerang, Australia. There arc four to five trihedral corner reflectors in each calibration array. The results after calibration of the gain of the corner reflectors are tabulated in table 4. Using the calibration coefficients required for this calibration, the AIRSAR data collected during the South American deployment were calibrated as described in [3]. This calibration includes absolute calibration, HH - VV Channel imbalance calibration, HH-VV phase calibration, cross-talk removal, and radiometric calibrations such as antenna pattern removal, system gains, and the effect of changing surface area as a function of incidence angle. The analysis of the AIRSAR data is difficult, as a wide range of incidence angles arc imaged within one scene, due to the low altitude of the aircraft. For this analysis, only data near the incidence angle of J-ERS-1 were used. Table 3 indicates that the L-band radar is calibrated to within about half a dB at the time of the overflight of the Rio Manu watershed,

May 18, 1993	Rosamond Dry Lake	-O.14± 0.61 dB
July 1, 1993	Rosamond Dry Lake	0.61± 0.31 dB
Sept 12, 1993	Kerang, Australia	-0.09± 0.80 dB

Table 4. AIRSAR absolute calibration residuals (I .-band)

J-ERS- 1 data was also acquired over the Rosamond Dry Lake calibration array in Southern California, (the same array that is used by AIRSAR to determine absolute calibration offsets), and at a calibration array deployed near Manaus, Brazil. The area was imaged on April 30, 1993 at the Rosamond array, and on July 6, 1993 at the Manaus array. The J- ERS-1 pass over the Rosamond Dry Lake is an ascending pass, while all other passes arc descending.

Analysis of the return from 8 foot trihedral corner reflectors present in full resolution images of the Edwards Air Force Base and Manaus, Brazil calibration sites generated the results of Table 5. In this table, Km represents the measured calibration offset for each corner reflector for NASDA format data while Kp represents the projected calibration offset provided by NASDA.

CR name	Seen e	Image ID	Overf 1 i gh t Date	Km (dB)	Kp (dB)	Km-Kp (dB)
EAB9 0	Edwards	c0077a10	93 Apr 30	-69.11	-68.50	-0.61
EAB7 0	Edwards	c0077a10	93 Apr 30	-69.35	-68,50	-0.85
EAB60	Edwards	c0077a10	93 Apr 30	-69.28	-68.50	-0.78
EAB50	Edwards	c0077a10	93 Apr 30	-69.30	-68.50	-0.80
EAB4 0	Edwards	c0077a10	93 Apr 30	-68.22	-68.50	0.28
MN5	Manaus	c0230b19	93 Jul 06	-68.19	-68.50	0.31

Km-Kp average = -0.41 dB
Km-Kp std. dev. = 0.55 dB

Table 5. J-ERS- 1 corner reflector measurements

To obtain Km, a 21 by 21 pixel box centered around the peak of the point target's return is selected. The noise and background level estimated from the non shaded area in Figure 1 is subtracted from the sum of the shaded portion which contains the point target's impulse response plus the contribution of noise and background return. The resulting impulse response is then used along with the point target's theoretical radar cross section and the image pixel spacing to calculate the calibration offset Km.

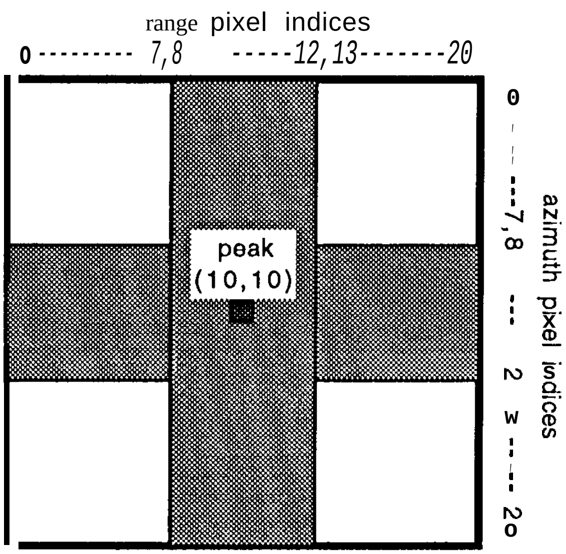

Figure 4. Corner Reflector Analysis

This indicates that at the time J-ERS- 1 imaged the corner reflectors at the calibration array in Rosamond, the instrument was very close to being calibrated. This is somewhat in disagreement with the rain forest measurements. However, as figure 3 showed, there are some long term drifts in the calibration of the J-ERS- 1 instrument that may account for the differences.

J-ERS-1 IMPULSE RESPONSE ANALYSIS

The impulse response analysis was also performed to analyze the return from the corner reflectors present in the Edwards and Manaus images mentioned above. Table 6 presents the results of this analysis which show the resolutions to be close to nominal, while the PSLR values suggest that the quality of the images is better than -10 dB.

CR name	Seen e	Image ID	inci angle (deg)	sl rng (km)	rng res (m)	azi res (m)	rng PSLR (dB)	azi PSLR (dB)
EAB9 0	Edwards	c0077a10	40.68	746.62	17.58	17 .19	-14.35	-20.37
EAB7 0	Edwards	c0077a10	40.71	746.95	17.97	17.97	-15.01	-21.38
EAB6 0	Edwards	c0077a10	40.75	74'/ .28	18.36	22.27	-10.54	-22.99
EAB50	Edwards	c0077a10	40.81	747.92	18.36	16.80	-15.85	------
EAB4 0	Edwards	c0077a10	40.88	748.58	19.14	17.58	-11.56	-19.20
MN3	Manaus	c0230b19	40.09	718.30	18.36	18.75	-13.66	-22.51
MN4	Manaus	c0230b19	40.50	722 .0.7	1.7.19	16.80	-15.98	-18.20
MN5	Manaus	c0230b19	40.97	726.51	18.75	17 97	-12.92	-23.15
AVERAGE					*18.22*	*18.17*	-13.73	-21.11
STANDARD DEVIATION					*0.62*	*1.78*	*1.96*	*1.93*
NASDA ' S NOMINAL VALUE					*18.00*	*18.00*		

Table 6. **Image Quality from Corner Reflector Analysis**

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References

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